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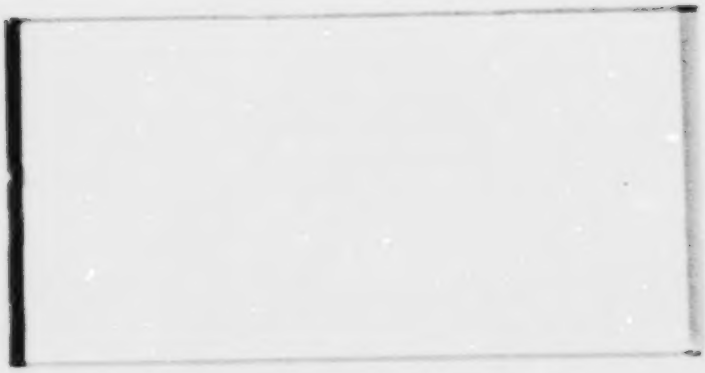

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A PLAN FOR RESEARCH BY THE ATMOSPHERIC RESEARCH SECTION IN SUPPORT OF ONTARIO HYDRO's NUCLEAR ACTIVITIES

Report No 84-134-K

G.L. Ogram - Atmospheric Scientist
O.T. Melo - Supervising Engineer
Atmospheric Research Section
Chemical Research Department

ABSTRACT

A plan for nuclear studies by the Atmospheric Research Section is presented. The need for research is discussed and research objectives are established. Recommended research activities include the study of fundamental processes governing the fate of emissions released to the atmosphere by Hydro's nuclear facilities and the development of improved transport models describing the fate of these emissions. A Sectional goal of providing technical expertise in the atmospheric sciences in support of Ontario Hydro's present and future nuclear activities is proposed. The plan covers a five-year time frame (1984-1988).

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To Mr. F.J. Kee
Director of Research

A PLAN FOR RESEARCH BY THE ATMOSPHERIC RESEARCH SECTION IN SUPPORT OF ONTARIO HYDRO's NUCLEAR ACTIVITIES

1.0 INTRODUCTION

1.1 Atmospheric Sciences and Nuclear Activities

Ontario Hydro's plans call for the increased use of nuclear generation. An important question concerns the actual and/or potential impact of nuclear generation on the public and the environment.

Small-scale emissions occur routinely; these are termed "chronic emissions." Limits on the dose to the population arising from chronic releases are set by the AECB. These limits are viewed as maximum values which must not be exceeded. The principle governing emission levels is that they be as low as reasonably achievable (ALARA). Generally, within Hydro, a target of 1% of the limit is set.

It is not possible to measure these doses directly. Consequently permissible release rates have to be inferred by calculating the resulting dose. The emission rate giving rise to the allowable dose is termed the derived emission limit (DEL). DEL's are thus secondary standards and must be calculated using a mathematical model that describes the environmental transport, fate and impact of the radionuclides emitted.

In the case of an accident, the possibility exists of significantly larger emissions of radioisotopes or toxic gases (eg, H_2S from the heavy water plants). These are termed "acute releases." While the probability of a severe accident requiring action to protect the public is judged to be small, the need to have systems available to predict the path and impact of the emitted plume has been well recognized.

A quantitative understanding of the transport and eventual fate of emissions in the atmospheric environment is therefore essential to deal with chronic and acute releases. When emissions to the atmosphere occur, the emitted plume is dispersed (transported and diluted) by winds and atmospheric turbulence. The emissions survive in the atmosphere until they are removed by precipitation scavenging

(wet deposition), by uptake to surfaces exposed to the atmosphere (dry deposition), or, in the case of radionuclides, undergo radioactive decay. While in the atmosphere, some species may undergo chemical transformations which may significantly affect their fate and impact.

The fate of releases can be predicted using a mathematical model that incorporates a sufficiently realistic description of these processes. Research may therefore be required to provide new knowledge regarding atmospheric processes and to develop new, or improve existing, atmospheric transport models.

In the following sections, needs are summarized, a goal for work by the Atmospheric Research Section in the nuclear area is suggested, and research objectives are recommended. The schematic shown in Figure 1 summarizes this plan and illustrates how the products of the research program described in Section 3.0 can be applied to meet the goals and needs outlined in Section 2.0.

1.2 History of Sectional Involvement in Nuclear Studies

The Atmospheric Research Section has carried out a number of tasks related to nuclear safety and environmental issues. These have included the implementation of computerized dispersion models for the Pickering '83 Contingency Exercise, preliminary studies of the dispersion climatology at NGS sites, respirator canister testing, and experimental studies of the dry deposition of elemental tritium. These activities are summarized in Appendix A.

Recently the National Working Group on Atmospheric Releases of Radioisotopes (NWG) has developed recommendations regarding atmospheric transport models to be used in the event of a contingency. Subsequently, Working Group #4 (WG4) has been advising the Ontario Ministry of the Solicitor General on this subject for the new provincial emergency plans. The Atmospheric Research Section has monitored the NWG activities and Section members have acted in an individual capacity as technical advisors on WG4.

While significant Sectional involvement in nuclear studies only began in 1981, the Section has carried out extensive studies of the atmospheric processes affecting releases from thermal generating stations at lakeshore sites. Much of the experience and information gained is also required in the nuclear case.

2.0 PROGRAM GOAL

The Atmospheric Research Section has the mandate to carry out research in the atmospheric sciences. Carrying out an effective research program will allow the Section to meet the goal of providing technical expertise in the atmospheric sciences in support of Ontario Hydro's present and future nuclear activities. This will include:

RESEARCH GOAL

Provide Technical Expertise in Ontario Hydro in The Atmospheric Sciences in Support of Ontario Hydro's Present and Future Nuclear Activities

RESEARCH OBJECTIVES

For Chronic and Acute Releases

- Carry out research to improve understanding of atmospheric processes
- Develop models describing fate of releases to atmosphere

APPLICATION OF RESEARCH PRODUCTS TO NEEDS: (DELIVERABLES)

CHRONIC RELEASES

- Quantitative and site specific assessment of performance of models presently used for impact assessment
- Improved models describing fate & impact of atmospheric releases for DEL's and impact assessment
- Improved site specific parameters for existing models (for transport, diffusion, transformation & deposition)
- Improved site specific dispersion and meteorological data
- Verified building wake cavity model

ACUTE RELEASES

CONTINGENCY RESPONSE

- Dispersion modelling schemes with optimization routines for contingency response to radionuclide releases
- Model for scenario setting
- Tracer techniques for scenario setting and/or contingency training
- Optimized field sampling procedures

CONSEQUENCE ANALYSIS

- Understanding of site specific dispersion & meteorology
- Appropriate transport modelling schemes

FIGURE 1

SCHEMATIC OVERVIEW OF PROPOSED RESEARCH PROGRAM

- doing research to solve outstanding problems and deal with future needs as anticipated by Research and other Divisions.

- acting as a source of information to other Divisions that have the mandate to deal with the safety, regulatory and operating requirements regarding emissions, and

- developing, testing and transferring, to users within Hydro, the systems and knowledge required to understand and predict the fate of atmospheric releases from Hydro's nuclear facilities.

A number of specific needs which may be addressed through research are listed below:

- A better understanding of radionuclide transport in the environment will (i) provide the basis for the technical evaluation of the performance of present DEL models; (ii) lead to greater confidence in DEL values; and (iii) make possible the improvement of models if necessary. Conservative (worst case) assumptions are made when information is lacking, hence improved information can justify less conservative DEL's.

- Development of new methods to supply site specific information will (i) assist interpretation of environmental monitoring data and optimization of sampling network design and (ii) support site evaluation studies, licensing procedures and accident consequence analysis.

- Expert knowledge of the fate of atmospheric releases will allow Hydro to interact knowledgeably with regulatory and other agencies (eg, in anticipating and dealing with potential changes in regulatory requirements, supporting export of nuclear-generated power, decommissioning, etc) and will help Hydro maintain public confidence in the nuclear program.

- A system for predicting, on a real time basis, the fate of emissions to the atmosphere is required for contingency response. Such a system will be used for (i) diagnostic purposes and (ii) decision making on protective actions and/or timing of controlled releases.

- Realistic contingency scenarios are required to test contingency response procedures and provide effective response training.

- Information may be required to support the introduction of new technologies such as fusion, reprocessing and waste disposal.

Research needs outlined here have been discussed with other Divisions. The perspective presented here is, however, that of the Atmospheric Research Section. In developing these plans a dual role for the Section was envisaged; ie, (i) acting as expert consultants to other Divisions and carrying out research on present problems (reactive research) and (ii) carrying out research to deal with anticipated needs (anticipatory research). This plan is also based on the judgement that it would be a prudent strategy for Ontario Hydro to develop, through research, a sound scientific understanding of the fate of emissions from its nuclear activities. This knowledge should go beyond what is required by present regulatory and operating requirements in order to be able to deal effectively with issues as they arise in the future.

3.0 RECOMMENDED RESEARCH ACTIVITIES

3.1 Overview

Recommended research activities are outlined below. Activities were divided into a number of program areas; atmospheric dispersion, transformation and deposition, and other issues. An overview of the present state of knowledge is given for each program area considered. An overall approach is suggested in each of these areas and some specific projects are recommended for initiation in the short term. Preliminary cost estimates are given in Appendix B. A summary of the objectives of the suggested program follows.

For chronic releases:

- develop improved models describing the fate of atmospheric releases, including dispersion, transformation and removal processes
- develop appropriate time averaged descriptions of dispersion at Hydro's nuclear sites under various meteorological conditions appropriate to each site
- carry out field studies to support the modelling effort and to develop new methods of obtaining site specific information
- quantify the error in model predictions through field studies and sensitivity analysis (this includes developing the information required to evaluate how well standard models perform at Hydro's sites)
- carry out research to improve the understanding of the chemical speciation of atmospheric emissions and their atmospheric transformation, removal and resuspension processes, where lack of knowledge leads to significant uncertainty.

For contingency response and consequence analysis:

- develop, verify and implement short- and medium-range, event-basis dispersion models incorporating transformation and deposition processes
- develop the techniques required to evaluate and verify these models at Hydro's nuclear sites
- develop procedures for optimizing contingency response model predictions by comparison to field measurements
- develop ways of providing a rapid response capability by interfacing on-line dispersion models with real time meteorological data
- develop the techniques required to understand and characterize the dispersion climatology at Hydro's nuclear sites and to supply the necessary meteorological input to the above models
- develop techniques to assist contingency simulation and response training.

Planned research has been directed towards areas in which present understanding has been judged to be potentially inadequate. However, it is sometimes difficult to judge the adequacy of present understanding of environmental transport as reflected in existing methodologies without having good site specific information to evaluate model performance. This program aims both to generate the necessary information to make this evaluation and to develop systems based on improved knowledge if required.

3.2 Research Program Area 1 - Atmospheric Dispersion at Ontario Hydro's Nuclear Sites

Ontario Hydro's major nuclear generating facilities are located at lakeshore sites. Dispersion climatologies of lakeshore sites are complex because of nonuniform topography and inhomogeneous meteorology and hence are not well understood. Physically accurate and verified dispersion models are thus not available for contingency response or assessment of the impact of releases. Models capable of dealing with dispersion phenomena exhibited at these sites need to be developed and/or verified.

Models presently used for operational and planning purposes may perform poorly in certain instances. For example, the performance of standard Gaussian models is known to depend greatly on the type of site at which they are used and the meteorological conditions. These models perform best under conditions of uniform terrain and homogeneous meteorology and are hence likely to perform less well at lakeshore sites. An estimate of the quality of model performance can only be obtained through site-related studies because each site will have differing atmospheric flow characteristics. (For example, the complexity of the possible dispersion conditions at Bruce is discussed by P.K. Misra in Ontario Hydro Research Division Report 80-375-K). This site specific information would provide the basis for evaluating the error incurred in present methods of calculating DEL's and of doing risk assessment or making dose projections for contingency response, due either to lack of realism in the models used or to uncertainty in model parameter values. This information is also essential to guide the development of improved models.

Any atmospheric releases from nuclear facilities will likely occur into the surface boundary layer because exhaust stacks are not significantly elevated above building height and the plume is not expected to be buoyant. Gaussian models assume vertical homogeneity in meteorological parameters. This is an invalid assumption in the boundary layer where wind speed and turbulence may increase with height. Gaussian models can therefore be inappropriate for treating ground- or near ground-level releases.

The applicability of a dispersion model at a particular site may be verified through the use of tracers, which may be either routine emissions or released tracer gases. Parallel meteorological and tracer studies would also contribute to the historical data base regarding the dispersion climatology at a site and would enhance the information available to other Divisions for site specific assessment purposes. The information obtained from such studies would allow Hydro to claim expert understanding of the atmospheric dispersion conditions at its nuclear sites.

More sophisticated dispersion models may require, or be able to make use of, more comprehensive meteorological input data. New meteorological monitoring techniques, able to provide better information, have recently become available and are being evaluated (eg, the Doppler acoustic sounder).

The approach taken in this plan is to provide a framework to guide the research necessary to meet the research objectives given earlier. Accordingly, detailed descriptions are only given for those projects which fit into this framework and which can be identified for initiation in the short term (ie, during 1984 or soon thereafter). The framework recommended for dispersion research is shown in Figure 2. Research activities are broken into three categories: dispersion models, meteorological instrumentation, and field verification techniques (including tracers). Anticipated research products are also shown.

It is apparent that research into dispersion should include both the development and implementation of theoretical models and the carrying out of field experiments. Information on the atmospheric transformation and removal processes undergone by releases (item 3.3 below) will be combined with descriptions of dispersion to provide complete atmospheric transport models.

Specific projects recommended for initiation in the short term are discussed below and shown in the schedule diagram, Figure 3. As indicated in the figure some of these projects are already underway. The figure also shows those projects within this subject area that are already completed (see Appendix A) and the relationship between those projects and the projects recommended here. The numbers refer to the project listing in Appendix A.

1. Development of the CRDM Computer Code

The CRDM (Continuous Release Dispersion Model) code was implemented by the Atmospheric Research Section for the Pickering '83 Contingency Exercise. The draft recommendation of WG4 is based on this model. This model is therefore expected to form the basis of the nuclear contingency response system to be used in Ontario.

The CRDM model was based on a similarity theory treatment of dispersion in the vertical. This type of model explicitly takes into account the vertical inhomogeneity in the wind speed and turbulence. This model, therefore, is particularly suited to the treatment of releases into the boundary layer (ie, ground- or near ground-level releases). Traditionally, Gaussian plume models have been used for contingency response. This model is thus expected to be a significant improvement.

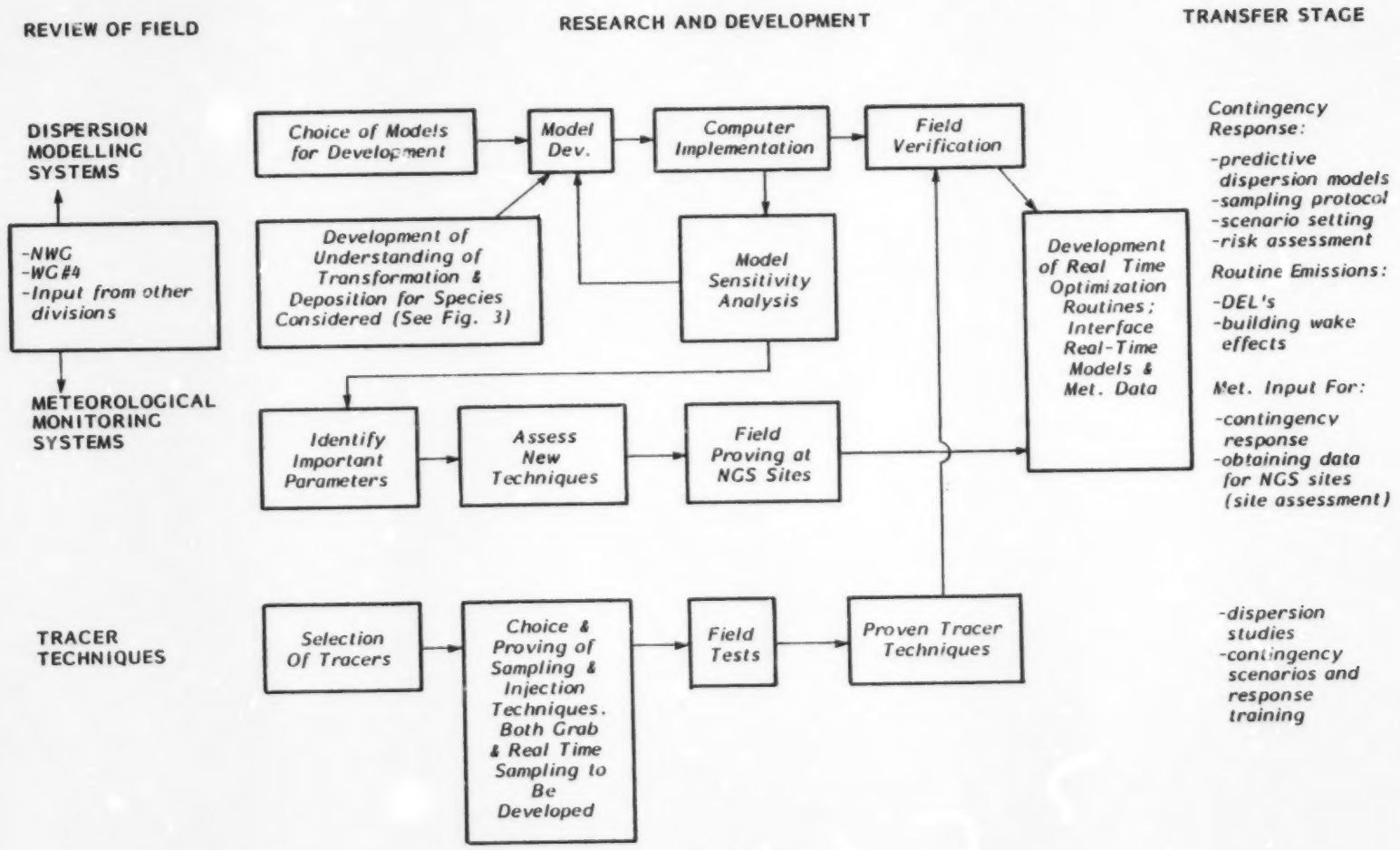

FIGURE 2

RESEARCH PROGRAM AREA 1 -
ATMOSPHERIC DISPERSION AT ONTARIO HYDRO'S NUCLEAR SITES

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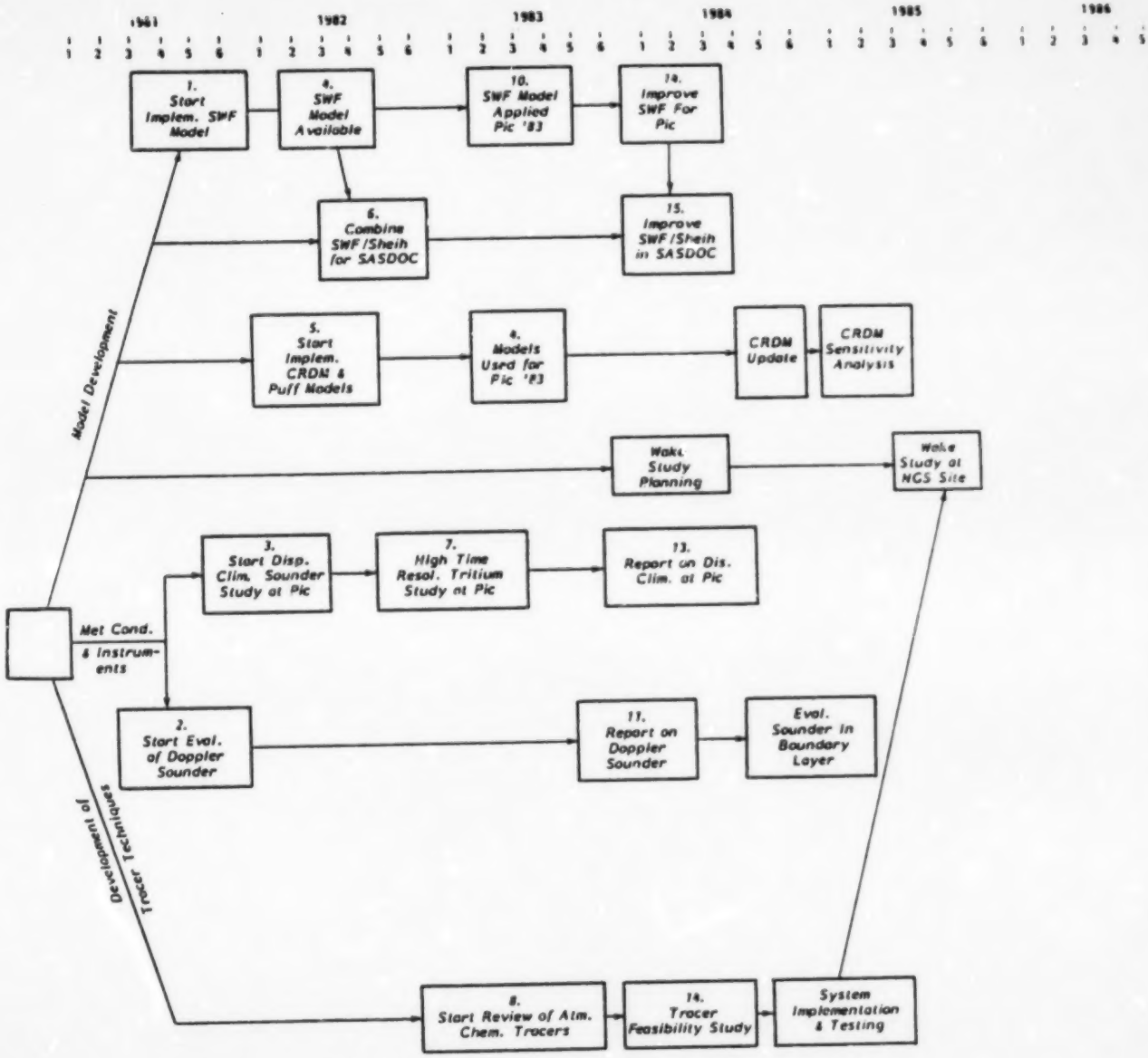
1981
1982
1983
1984
1985
1986
1. Start Implem. SWF Model
4. SWF Model Available
10. SWF Model Applied Pic '83
14. Improve SWF For Pic
6. Combine SWF/Sheih for SASDOC
15. Improve SWF/Sheih in SASDOC
Model Development
5. Start Implem. CRDM & Puff Models
9. Models Used for Pic '83
CRDM Update
CRDM Sensitivity Analysis
Wake Study Planning
Wake Study at NGS Site
3. Start Disp. Clim. Sounder Study at Pic
7. High Time Resol. Tritium Study at Pic
13. Report on Dis. Clim. at Pic
Met Cond. & Instrumentation
2. Start Eval. of Doppler Sounder
11. Report on Doppler Sounder
Eval. Sounder in Boundary Layer
Development of Tracer Techniques
8. Start Review of Atm. Chem. Tracers
14. Tracer Feasibility Study
System Implementation & Testing

FIGURE 3

SCHEDULE DIAGRAM FOR STUDIES OF ATMOSPHERIC DISPERSION AT ONTARIO HYDRO'S NUCLEAR SITES (SHOWING COMPLETED AND ONGOING STUDIES AND STUDIES RECOMMENDED FOR THE SHORT TERM) (SEE APPENDIX A FOR A DESCRIPTION OF THE PROJECTS LISTED)

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The code requires the addition of routines to describe wet deposition, above-ground releases, and horizontal diffusion. In addition, it would be desirable to carry out an analysis of the sensitivity of model output to model input parameters. This is necessary to quantify the error in model predictions due to uncertainty in input data or lack of persistence of particular meteorological conditions. It would also establish the most effective parameters to be adjusted in any optimization routine which uses comparisons to field measurements to refine predictions. The development of a suitable optimization routine could form the basis of a subsequent project.

The usefulness of dispersion modelling systems for contingency response would be enhanced by being able to more quickly provide a picture of dispersion conditions at the site in the event of an emergency. This can be best done by providing an on-line modelling facility which accepts meteorological data on a real time basis. Ways of effectively doing this should be investigated.

2. Development of Wind Field Models

It has been recognized by the NWG and WG4 that most existing models suitable for implementation for contingency response fail in two important areas. Firstly, the mesoscale is difficult to treat well and, secondly, the short-range models do not take into account the complicated dispersion patterns at lakeshore sites. There are many potential ways of dealing with these problems, however, to be practicable, it is desirable to have a model that works with a minimum amount of input data and does not require large amounts of computer time to run.

A model that has the potential to meet these requirements is the surface wind field (SWF) model available within the Atmospheric Research Section.

This model runs on input data from one site and uses surface topography to generate a wind field. The model thus may be readily made site specific. The model requires site verification, optimization to treat the microscale, and improved time resolution to be useful for contingency response. Ways of combining this model with a description of vertical transport need to be investigated to provide a full three-dimensional picture of dispersion.

The model is likely to be used by Health and Safety Division for exercise scenario setting in the near future. It is at present combined with the Sheih puff model for this purpose. The computer code is known as SASDOC (Safety Services Dose Calculation).

It is recommended that the development of the SWF model be pursued as a promising means of obtaining a predictive wind field model. This activity will allow the Section to contribute significantly to developments in this area and provide a model facility of use to other groups within Hydro. Of course, considerable activity is also going on elsewhere. These activities should be monitored for any significant developments and the merits of the SWF model re-evaluated in the light of any advances.

3. Development of Meteorological Instrumentation to Characterize Site Dispersion Climatology

The NWG and WG4 have surveyed the meteorological instrumentation required to supply the input to dispersion models to be used for real time predictions in the event of an emergency. As a future alternative to standard instrumentation WG4 has suggested that Doppler acoustic sounders have the potential of providing comprehensive information at reasonable cost. As the systems are ground-based remote sensors, they are more easily maintained than tall meteorological towers.

The Section already has a program underway which involves the evaluation of a Doppler sounder at various sites. It is recommended that this program be continued with the potential application to nuclear sites being kept in mind. The Doppler sounder can also provide meteorological model verification and assist the intepretation of tracer studies.

The Section has recently acquired a high frequency option for the Doppler sounder. This should improve vertical resolution and enable the lower regions of the atmospheric boundary layer to be probed (to about 50 m, below which tower data can be used). This will potentially provide information about the atmosphere at heights characteristic of release heights from nuclear plants. This includes vertical profiles of wind speed and direction and their variance, the height of the surface mixed layer and the depth of inversions.

The development of new meteorological monitoring techniques should be evaluated on a continuing basis in regard to their potential for supplying useful information at nuclear sites. Ways of optimizing output to provide direct input to real time dispersion systems should be investigated (see Item 1).

4. Tracer Studies

Field studies involving tracers will be required to obtain definitive, site specific information regarding dispersion, and to test the performance of theoretical models. Tracer releases may also be used for contingency scenario setting and for contingency response training purposes. CEGB in the UK have developed tracer techniques for the latter purpose.

The capability to carry out tracer measurements is being developed within the Section. This includes the acquisition and/or development and testing of tracer sampling and release equipment. It is recommended that systems be field tested in 1984. Based on this experience and information gained from climatological studies at nuclear sites, tracer studies can be planned. It may be most useful to plan these initially for the Pickering and Darlington sites due to the importance of dispersion at these sites because of the proximity of large centers of population.

5. Wake Studies at Nuclear Sites

Because of the low effective release height, the building wake is likely to affect short-range dispersion. It has also been pointed out by Design and Development Division that the resulting wake recirculation may lead to emissions being returned to ventilation intakes, thereby leading to the possible contamination of the building air supply.

The effect of building wake on ventilation intake air quality has been studied using simple analytical models, based on mass conservation considerations, and wind tunnel simulations carried out by the University of Western Ontario (W. Moroz, E. Laratta and A. Hoffer, ESAD Report No 81003). It was concluded that this problem will only be understood in a quantitative way by on-site field studies which would allow improved predictive models to be formulated.

Accordingly, the Atmospheric Research Section and ESAD are carrying out the preliminary design of such a study. The study would involve the release of tracers into the wake, with comprehensive sampling being done in the downwind wake cavity and beyond, under selected meteorological conditions.

Interest in such a study goes well beyond the application to nuclear sites and covers the general problem of the release of toxic materials from building structures.

A field study of the type indicated could also give information regarding short-range dispersion at nuclear sites (Item 4 above). The aerodynamics of the flow around the building is expected to enhance plume dilution.

3.3 Research Program Area 2 - Atmospheric Transformation and Deposition

3.3.1 Background

The impact of a release will depend both on the type of radionuclide emitted and on its chemical form. This will determine the rate of uptake and retention by living organisms, as well as rates of removal from the atmosphere. It is, therefore, important to know the chemical form in which radionuclides are released and to understand chemical reactions undergone within the atmosphere.

The major radionuclides released to the atmosphere by CANDU systems are listed below in order of anticipated relative importance (according to % DEL except for C-14) for the cases of chronic and acute emissions.

Chronic	Acute
Tritium	Noble gases
Noble gases	Radioiodine
Carbon-14	Tritium
Radioiodine	Particulate matter
Particulate matter	

Each species is discussed separately in the following sections.

3.3.2 Tritium

Tritium is a uniquely significant emission to the atmosphere from CANDU systems because of the use of heavy water moderator and heat transfer systems. Tritium is usually released in the form of tritiated water with the possibility of some elemental tritium and tritiated hydrocarbons. The introduction of the tritium recovery facility and fusion technologies will lead to the potential of significant releases of tritium in the elemental form.

A plan for tritium-related studies within the Section has been presented elsewhere (G.L. Ogram, Ontario Hydro Research Division Report 83-86-R). Attention was focussed on the processes undergone by the likely chemical forms of tritium within the atmosphere. Important gaps in the understanding of these processes were identified and an attempt was made to set research priorities. This work is presently underway.

The objectives were to:

1. Determine atmospheric chemical transformation mechanisms and rates for the various chemical forms of tritium of importance, and determine the effect of environmental conditions on these rates.

2. Determine atmospheric removal rates for the tritium species of interest. This will include developing an understanding of wet and dry deposition and the dependence of these processes on various environmental factors and the isotopic composition of the species under consideration.

3. Develop transport models describing dispersion, transformation and removal processes for tritium species in the atmosphere. From these develop simple parameterized models suitable for use in atmospheric transport calculations used to determine the impact of releases.

A schematic summarizing the proposed approach to tritium research activities and their anticipated products is given in Figure 4.

Recommended projects are listed below. A suggested schedule is given in Figure 5. The diagram also shows tritium-related work which is ongoing or already completed (see Appendix A).

1. Deposition of Elemental Tritium

Tritiated water vapour (HTO) is approximately 10,000 times more radio-toxic than elemental (or molecular) tritium (HT, T_2). Consequently, the impact of a release of T_2 will depend strongly on its rate of conversion to HTO within the environment.

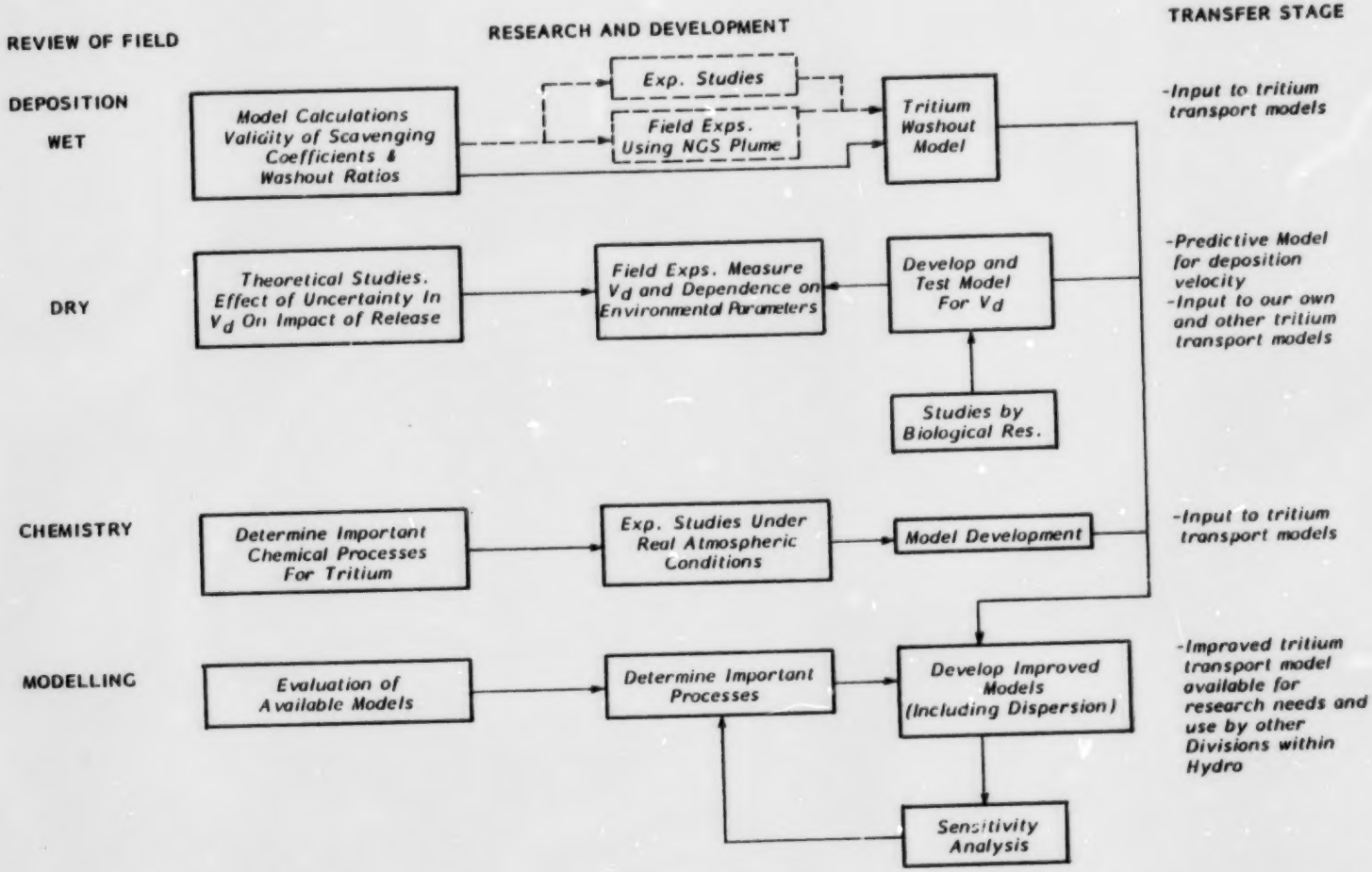
REVIEW OF FIELD
RESEARCH AND DEVELOPMENT
TRANSFER STAGE
DEPOSITION
WET
Model Calculations Validity of Scavenging Coefficients & Washout Ratios
Exp. Studies
Field Exps. Using NGS Plume
Tritium Washout Model
-Input to tritium transport models
DRY
Theoretical Studies. Effect of Uncertainty In V_d On Impact of Release
Field Exps. Measure V_d and Dependence on Environmental Parameters
Develop and Test Model For V_d
Studies by Biological Res.
-Predictive Model for deposition velocity
-Input to our own and other tritium transport models
CHEMISTRY
Determine Important Chemical Processes For Tritium
Exp. Studies Under Real Atmospheric Conditions
Model Development
-Input to tritium transport models
MODELLING
Evaluation of Available Models
Determine Important Processes
Develop Improved Models (Including Dispersion)
Sensitivity Analysis
-Improved tritium transport model available for research needs and use by other Divisions within Hydro

FIGURE 4

RESEARCH PROGRAM AREA 2-ATMOSPHERIC TRANSFORMATION AND DEPOSITION OF TRITIUM

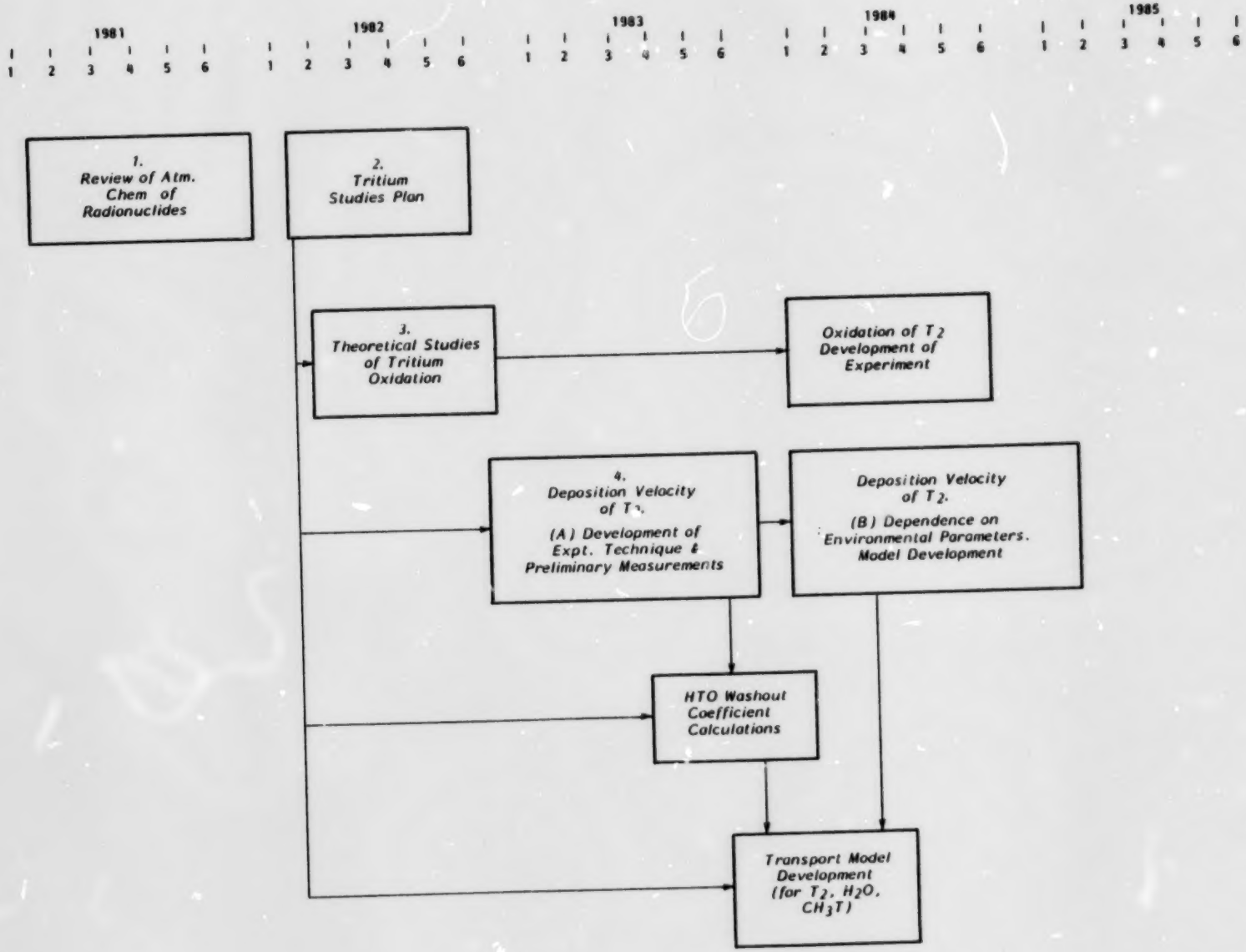
1981
1982
1983
1984
1985
1 2 3 4 5 6
1. Review of Atm. Chem of Radionuclides
2. Tritium Studies Plan
3. Theoretical Studies of Tritium Oxidation
Oxidation of T_2 Development of Experiment
4. Deposition Velocity of T.
(A) Development of Expt. Technique & Preliminary Measurements
Deposition Velocity of T_2.
(B) Dependence on Environmental Parameters. Model Development
HTO Washout Coefficient Calculations
Transport Model Development (for T_2, H_2O, CH_3T)

FIGURE 5

SCHEDULE DIAGRAM FOR STUDIES OF
ATMOSPHERIC TRANSFORMATION AND DEPOSITION OF TRITIUM

On the basis of present knowledge, the dominant process for the oxidation of T_2 in the lower atmosphere is the action of soil microorganisms. The effect of this process on a plume of elemental tritium is conveniently parameterized by defining a deposition velocity to soil for oxidation.

An experimental program is underway to make field measurements of deposition velocities. A preliminary investigation of the effect of season and ground cover is being carried out at the Wesleyville B site. This project is being co-funded by the Canadian Fusion Fuels Technology Project.

This study will be expanded to investigate the effect of various important environmental factors on deposition velocities. The objective is to use this information, together with that obtained by Biological Research in their laboratory studies of the uptake by soils under controlled conditions, to develop a predictive model for deposition velocity.

2. Tritium Washout

The literature contains various experimental and theoretical studies of the scavenging of tritiated water from the atmosphere by rain droplets. A number of ways of parameterizing this process for modelling purposes are available. However, a careful comparison of alternative approaches has not been carried out.

It is therefore recommended that a review of the subject be carried out with the objective of establishing simple but sufficiently realistic methods of parameterizing the washout of HTO. Possible ways of treating scavenging by snow should also be investigated.

In the longer term the feasibility of inferring washout rates, by measuring the tritium content of rain that has fallen through a NGS plume, should be investigated.

3. Tritium Transport Modelling

The development of a tritium transport model is recommended. This model should incorporate state-of-the-art understanding of the atmospheric processes undergone by elemental tritium, tritiated water and tritiated hydrocarbons. The atmospheric model should eventually be combined with other model components describing the pathways and fate of tritium in the hydrosphere and biosphere.

The model should provide a means of estimating, through sensitivity analysis, the uncertainty due to lack of fundamental knowledge. This capability would allow use of the model in developing, prioritizing and evaluating research projects.

A simplified form of the model could be transferred to other Divisions for their use in the assessment of the impact of releases.

4. Oxidation of Elemental Tritium

As discussed in Item 1, under most conditions the dominant environmental mechanism for the oxidation of T_2 is expected to be the action of soil micro-organisms. However, it is also known that gas phase reactions exist which oxidize T_2; for example, the reaction with the hydroxyl radical, OH. Under certain conditions this reaction may be important.

A means of directly measuring the rate of T_2 oxidation in the ambient atmosphere has been proposed (Ontario Hydro Research Division Report No 83-86-R). A preliminary study should be carried out to determine whether a detectable amount of HTO is formed under typical conditions to enable meaningful measurements to be made.

3.3.3 Carbon-14

CANDU systems emit significant amounts of C-14. Present evidence suggests that it is emitted as CO_2, CO, CH_4 and other hydrocarbons.

Preliminary analysis indicates that the short-term impact of these emissions is extremely small. However, due to the long half-life of C-14 (5730 years) the time integrated dose may be substantial. Design and Development Division have developed a simple model describing the short-range transport of C-14 near nuclear stations. The model has some possible deficiencies (the C-14 is assumed to be all CO_2 and deposition is treated without regard for gradients in specific activity).

There is scope for the investigation of the effect of the chemical form of C-14 on its fate and impact. However, in the short term, research into dispersion at nuclear sites and atmospheric transformation and deposition of tritium is seen as of higher priority.

3.3.4 Radio-Iodine

Radio-iodine is expected to be important in releases from severe accidents. The extent and chemical speciation of the release will be strongly dependent on chemical and physical processes occurring within confinement. These processes are at present being studied by the Nuclear Studies and Safety Department who have contracted out work to AECL-WRNE. Other groups in the US and elsewhere are working on similar problems. It is interesting to note that the experience at Three Mile Island indicated that much of the iodine was captured in solution. Present analyses of accident scenarios may thus significantly overestimate iodine releases. The chemical forms released appear to be I_2, CH_3I and a species thought to have the chemical form HOI. Information regarding the transformation and deposition of these species is sparse. A review of the state of knowledge is recommended. This would establish whether research is necessary, or whether it would be sufficient to limit Sectional activity to remaining conversant with the literature and activities elsewhere.

3.3.5 Noble Gases

These are important components of both acute and chronic emissions. Under atmospheric conditions they do not undergo chemical reactions and are not significantly scavenged by precipitation or lost by dry deposition. The important processes to be considered are, therefore, dispersion and radioactive decay. Kr-85 is the only species with a sufficiently long half life (10.76 years) to remain in the environment for long periods. Most other species of interest have half lives of the order of weeks or days or less. On decay, radioactive daughter products may be formed (eg, radioisotopes of Cs, Rb, Sr). The environmental pathways of these daughter species may need to be investigated.

3.4 Other Issues

The expertise gained by carrying out research in the atmospheric sciences may have spin off applications. An example is the respirator canister testing (see Appendix A) where expertise in designing gas handling and calibration systems and availability of monitoring equipment was essential.

The potential of expanding this work to characterize the behaviour of trapping materials for various species (eg, for radio-iodine scrubbing) is being investigated on a preliminary basis.

Other issues that may require work are:

- the dispersion of heavier than air clouds (H_2S),
- combustion of accidental releases of H_2S and resulting H_2S to SO_2 concentration ratios downwind of the spill or ignition zone,
- dispersion of spilled material in the case of a transportation accident.

4.0 CONCLUDING REMARKS

A plan for nuclear-related research by the Atmospheric Research Section has been described. The plan covers an approximately five-year time frame (1984-1988). Because needs and priorities may change within this time period, plans and progress should be evaluated at yearly intervals. In addition, as with any research, there are imponderables which cannot be assessed at the outset of the program. A regular review will enable the implications of these to be taken into account.

Some of the projects discussed are of interest to users outside Ontario Hydro. External co-funding should be pursued in these cases.

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Approved:

D. Harrison
Manager
Chemical Research Department

GLO/OTM:mf

Submitted:

G.L. Ogram
Atmospheric Scientist
Atmospheric Research Section

O.T. Melo
Supervising Engineer
Atmospheric Research Section

APPENDIX A

SECTIONAL PROJECTS RELATED TO NUCLEAR ISSUES

A. Previous and Ongoing Sectional Projects Shown in Figure 3. (Schedule Diagram for Studies of Atmospheric Dispersion at Ontario Hydro's Nuclear Sites)

Event	Description
-	Topography, flow patterns and dispersion characteristic of the Bruce site analyzed in a preliminary way. Lake and topographical effects found to be very important. Report 80-375-K produced by P.K. Misra.
1,4	Surface wind field model developed by Danard, in which topographical and thermal effects are considered, was implemented on UNIVAC computers. Report 81-500-K produced by Y. Tam (PRF 35-641, Sept 8/81-May 11/82). "Applications of Mesoscale Modelling at Ontario Hydro." A.C. McMillan and Y.T. Tam. Proceedings of Mesoscale Meteorology Research Planning Workshop, AES, Toronto, 1983.
2,11	Doppler SODAR acquired in May, 1982 and evaluated at Nanticoke and other sites with partial support from TGD. Reports 82-138-K and 83-382-K produced by Y. Tam and C. Kerry (PRF's 35-105, Nov 20/81-Nov 4/83; and 35-654, Nov 25/82-Nov 4/83).
3,13	Dispersion climatology of Pickering site studied using an array of SODARS and other supporting meteorological instrumentation. Reports C83-3-K, C83-14-K, C83-47-K and C83-115-K by A. Lemyk and D. Wenglewick document the data. Summary report by Y. Tam nearing completion (PRF's 35-644, Feb 1/82 to present; 35-603, Mar 1/83 to present; and 35-602, Mar 30/83 to present). "Application of Acoustic Sounding to Nuclear Environmental Issues." A.C. McMillan, C.W. Kerry and A. Lemyk. Proceedings of 3rd Annual Conference of the Canadian Nuclear Society, Toronto, June 9, 1982.
5,9	Agreed to participate in planning of Pickering '83 exercise. Implemented AES's PUFF model and a published model for continuous releases, CRDM, on our computer. Reports C83-75-K, 83-278-K and 83-277-K produced by S. Wright and A. McMillan (PRF 35-532, Aug 23/82-June 10/83).
6	Surface wind field model combined with Sheih's puff model and implemented on UNIVAC computer for use by H&S Division in their SASDOC package. Report 82-138-K prepared by Y. Tam (PRF 35-110, June 28/82-Dec 9/82).

Event	Description
7	Cooperated in a study of tritium concentration in air with H&S Division. High time resolution measurements made by H&S were supported with meteorological measurements made by us. Report prepared by A. McMillan (PRF 35-649, Aug 27/82-June 30/83).
8	Atmospheric chemical tracers reviewed at the request of TGD. Report 83-212-K prepared by A. Kalvins (PRF 35-113, Oct 4/82-present).
10	Surface wind field model was applied to the two days of weather simulated in Pickering '83 exercise. Report 83-322-K prepared by Y. Tam and G. Ogram (PRF 35-536, May 16/83-Aug 12/83).
12	Atmospheric chemical tracer feasibility study prepared at the request of TGD. Report under preparation by A. Kalvins (PRF 35-103, May 20/83-present).
14,15	Improved the surface wind field model/Sheih puff model component of SASDOC at the request of H&S Division (PRF's 35-104 and 35-302, Jan 1/84-present).

B. Previous and Ongoing Sectional Projects Shown in Figure 5. (Schedule Diagram for Studies of Atmospheric Transformation and Deposition of Tritium)

Event	Description
1	Transformation and deposition processes reviewed for radionuclides of importance in routine releases (Tritium and Carbon-14). Report 82-84-K produced by G. Ogram (PRF 35-575, June 19/81-April 22/83).
2,3	Plan developed for studies regarding the atmospheric fate of tritium. Detailed study of the processes responsible for oxidizing atmospheric T_2 carried out. Reports 82-449-K and 83-86-R produced by G. Ogram (PRF 35-576, Jan 13/82 to Mar 23/83).
3	Effects of release height and atmospheric stability on rate of T_2 oxidation, studied. Report C82-141-K by A. Ciraco and paper submitted to "Health Physics" by G. Ogram (PRF 35-580, Sept 30/82 to Mar 23/83).
4	Experimental technique to make infield measurements of deposition velocity of T_2 developed. Preliminary measurements made at Wesleyville site. (PRF's 35-303 and 35-102, project partially funded by Canadian Fusion Fuels Technology Project). Began April 30/83, project ongoing.

C. Other Projects

Extensive tests of respirator canisters used at the Bruce Heavy Water Plant site. Performance was tested at various temperatures and loadings of H_2S and SO_2 to ensure canisters met specifications. Partially supported by RMEP and H&S Division. Reports 83-154-H and 83-159-H prepared by O.T. Melo (PRF 35-118, Dec 15/82 to May 3/83; PRF 35-119, Feb 1/83 to May 3/83; PRF 35-511, Mar 30/83 to May 3/83; PRF 35-120, Oct 1/83-present).

APPENDIX B

ESTIMATED PROGRAM COSTS

Program	Total Cost, K$ (Labour, Including Overhead, and M&E)	Year
Dispersion at NGS Sites	390	1984
	438	1985
		1986
Fate of Tritium	205	1984
	205	1985
		1986
Other Nuclides and Other Issues	65	1984
	65	1985
		1986